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ORIGINAL RESEARCH

# Effects of CAD/CAM insoles and exercise on medial longitudinal arch and foot function in adolescents with flexible pes planus

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**Abstract**

The aim of our study was to investigate the effects of CAD/CAM-produced insoles and exercise on foot function and medial longitudinal arch (MLA) flexibility in adolescents aged 10-19 years diagnosed with painful flexible pes planus. A total of 42 individuals with painful flexible pes planus were divided into 2 groups by computer-aided randomization method, 21 individuals were included in the insole group and 21 individuals were included in the insole plus exercise group. Foot function index (FFI) was used to evaluate foot function of adolescents with painful flexible pes planus and navicular drop test (NDT) was used to determine medial longitudinal arch flexibility. Post-treatment navicular drop test scores in adolescents with painful flexible pes planus were significantly lower in the insole and insole plus exercise groups. ($p<0.001$), In the insole plus exercise group, especially in the right foot, the difference value of the navicular drop score after treatment was found to be higher than before treatment ($p<0.01$). Foot function index sub-parameters and total score were found to be significantly lower in both groups after treatment ($p<0.001$), but there was no difference between the groups ($p>0.05$). In conclusion; it was found that CAD/CAM insoles improved FFI parameters in adolescents with painful flexible pes planus. However, it was found that the effects of sole insoles and exercise plus insoles were similar on these parameters and that exercise has no additional benefit over insoles. However, it was found that exercise was more effective in improving the amount of navicular drop.

## Introduction

Flexible pes planus (flexible flat feet) is characterized by the collapse of the medial longitudinal arch (MLA) during loading on the foot and the arch returning to its original position when the load is removed. In contrast, in rigid pes planus deformity, the arch is constantly low regardless of the load and there is a structural deformity (Harris et al., 2004). Flexible pes planus is common in children and adolescents and can mostly correct itself spontaneously during the developmental process; however, it requires intervention in symptomatic and painful cases (Choi et al., 2020). The prevalence of pediatric pes planus varies between 48.5% and 77.9% in children aged 2-16 years (Chen et al., 2014; Mackenzie et al., 2012). In 10% of these individuals, treatment is required to prevent secondary deformities that may occur in the future (Jafarnezhadgero et al., 2020). Some factors such as structural laxity affecting ligaments and joints, age, excess weight or obesity, and loss of strength contribute to pes planus (Lin et al., 2001; Mackenzie et al., 2012).

Pes planus deformity can be seen as symptomatic and asymptomatic, and symptomatic pes planus usually requires intervention. Typical features of symptomatic pes planus include foot pain, fatigue, functional impairments such as tripping or falling, proximal joint problems, and decreased quality of life due to these. Treatment is usually multifaceted, including surgical and conservative interventions. The treatment methods applied vary from person to person, depending on age and underlying etiology.

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Conservative interventions include shoe recommendations, foot orthoses, stretching and strengthening exercises. However, there is still little guidance on what is an appropriate and proven intervention (Choi et al., 2020; Pinney et al., 2006; Harris et al., 2004).

The most commonly used podiatric intervention to support the arch in pes planus deformity is foot orthoses (Whitford et al., 2007). The use of insoles, which is frequently used in pes planus deformity, prevents unnecessary loads on the structures by supporting the MLA and helps to achieve normal foot alignment. When the literature is examined, it has been seen that the load distribution on the foot has been tried to be normalized with different shaped insoles made for patients with pes planus and improvement in symptoms has been achieved (Jafarnezhadgero et al., 2020; Taşpınar et al., 2017; Shih et al., 2011; Eng et al., 1993).

Exercise is very important in adolescents with pes planus deformity in the adolescent period. Studies have proven that exercise is effective in improving MLA height, navicular drop, foot posture, plantar pressure distribution, pain, balance and walking performance, intrinsic and extrinsic muscle strength (Ünver et al., 2019; Alam et al., 2019). Exercises aimed at increasing intrinsic muscle strength and improving ankle stabilization have been included in treatments (Blasimann et al., 2015). Recent studies have indicated that short foot exercise significantly increases the muscle activity of the abductor hallucis, flexor digitorum brevis and quadratus plantae. It has been observed that short foot exercise increases the activity of the abductor hallucis muscle 4 times more compared to the towel curl exercise (Haun et al., 2020; Mckeon et al., 2015). When we look at the literature, while there are many studies using insoles made by taking standard measurements for individuals with pes planus, studies on personalized CAD/CAM insoles are limited (Yurt et al., 2019). Insoles produced with the CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) method are designed with personalized foot pressure mapping and 3D foot scanning. Therefore, it eliminates any differences that may occur due to the operator and ensures that the application is more accurate and standard. This method enables more accurate support of the medial longitudinal arch and optimum pressure distribution (Xu et al., 2019). It allows for a successful application without requiring much experience. It contributes to the normalization of biomechanical loading in the long term by supporting the dynamic stabilization of the arch, especially in adolescents with flexible flat feet (Yurt et al., 2019). Traditional method insole application produced according to metric measurements taken from the individual's foot is an application that requires experience. Also, manufacturing differences due to the operator may occur. In addition, there are very few studies examining insoles and additional exercises in individuals with pes planus (Andreasan et al., 2023; Kim & Kim, 2016; Kırmızı et al., 2024). However, no studies have been found on flexible pes planus adolescents between the ages of 10-19. Current studies have generally been conducted on adult individuals, and randomized controlled studies in the adolescent age group are insufficient (Andreasan et al., 2013). In addition, no study has been found examining the effects of using CAD/CAM insoles together with exercise in adolescents. Our study aims to fill this important gap and investigate the possibility of achieving functional gains with early intervention. Exercise is very important for adolescents with pes planus to strengthen the foot muscles, prevent MLA from falling, and improve foot stability. Studies have reported that individuals with pes planus have lower tibialis posterior and plantar flexor muscle strength and shorter Achilles tendons compared to those with normal MLA (Aenumulapalli et al., 2017). In addition, a systematic review published in 2023 concluded that short foot exercises (SFEs) performed for at least five weeks are effective in improving foot posture in adults with flat feet; however, it was noted that randomized controlled trials with details on the number and frequency of exercises are needed (Hara et al., 2023).Various exercises have been used in the literature for adolescents with pes planus, but a definitive exercise protocol has not been specified. The purpose of our study is to examine the effects of insoles produced with the CAD/CAM method and exercise on foot function and MLA flexibility in adolescents between the ages of 10-19 diagnosed with painful flexible pes planus.

## Methods

Our study was conducted in the Foot Analysis Clinic of a health center in Denizli province with a total of 42 individuals between January 2019 and November 2019. This study was approved by the Pamukkale University Clinical Research and Ethics Institution on 22.01.2019 with the file number 60116787-020/5952. Informed consent was obtained from all participants and their parents. Our study was conducted in accordance with the World Medical Association Ethical Rules (Declaration of Helsinki).

## Participants

The study included individuals with bilateral flexible pes planus diagnosed by a physician using the Navicular Drop Test ≥10 mm and who had clinical examination findings, were right dominant between the ages of 10-19, had a pain score of at least 3.5 according to the Visual Analog Scale (VAS), volunteered to participate in the study, and had no other health problems; while individuals who had another foot deformity other than pes planus, had undergone lower extremity surgery, had an orthopedic problem that could affect walking, had a condition that could affect cardiovascular performance, had a cognitive disorder that could affect compliance and cooperation with tests and professional athletes were excluded. A total of 54 individuals who agreed to participate in the study were evaluated. 9 individuals who did not meet the inclusion criteria were excluded from the study. The remaining 45 individuals were divided into 2 groups as the insoles group (n: 22) and the insoles plus exercise group (n: 23) using the computer-assisted randomization method. 1 individual in the insoles group was excluded from the study because they did not use the insoles and 2 individuals in the insoles plus exercise group were excluded because they refused to do the exercises. As a result, the study was completed with the participation of 42 individuals in total, 21 individuals in the insoles group and 21 individuals in the insoles plus exercise group.

## Procedure

After obtaining informed consent from all individuals participating in the study; demographic information of the individuals was recorded. MLA flexibility was assessed with the navicular drop test and foot function was assessed with the foot function index. All groups were given personalized insoles produced with the CAD/CAM method and were asked to use these insoles for 8 weeks. All insole applications were placed inside walking type sports shoes after removing the inner lining of the shoe. Individuals were asked to wear these shoes at least 3-4 days a week and during active standing periods. One group was given exercises in addition to the insoles. Individuals were re-evaluated after an 8-week follow-up. All evaluations and insoles practice were performed by the same physiotherapist.

### *Demographic information*

The individuals' age, height, body weight, and body mass index were recorded using a face-to-face interview method and a prepared evaluation form.

### *Navicular drop test*

The navicular drop test is a test obtained by subtracting the navicular height measured while standing and weight is applied to the foot from the navicular height measured in the sitting position without weight being applied to the foot (Ünver & Bek, 2014). While individuals were sitting on a chair with bare feet, the navicular tubercle was marked on both feet, and then a mark was placed on a card with the lower edge on the floor at the level of the navicular tubercle. The individuals were then asked to stand up and the navicular tubercle level was marked again on the same card while full weight was applied to the foot. The distance between the two lines was recorded in mm as the amount of navicular drop instantly. A navicular drop of 6-9 mm was considered normal MLA, and 10 mm and above was considered pes planus (Morrison et al., 2003).

### *Foot function index*

Foot function index (FFI); consists of 23 items with 3 subgroups: pain, disability and activity limitation. The pain subscale, which includes nine items, measures the level of foot pain in various situations, while the disability subscale, which includes nine items, determines the degree of difficulty in performing various functional activities due to foot problems. The activity limitation subscale, which includes five items, evaluates activity limitations due to foot problems. Individuals scored all items with VAS, considering their foot conditions a week ago. To calculate the subscales and total score, the scores of each item were added, divided by the sum of the maximum scores of the items and multiplied by 100. Higher scores indicate more pain, disability and activity limitation (Anaforoğlu et al., 2018).

### *CAD/CAM insole*

CAD/CAM insole includes computer-aided design and computer-aided manufacture stages. After the foot sole pressure measurements of all individuals were performed on the electronic ground, insole modeling was performed on the computer. According to the foot sole pressure measurement, medial longitudinal arch, transverse arch and medial heel wedge additions were made in the insole design developed with the modeling program. After the design was completed, the modeling process was performed using EVA with a hardness degree of 50 on the computer-aided Computer Numerical Control (CNC) machine.

### Exercise

The exercise protocol was composed of exercises that are easy to apply in the adolescent population and have been proven effective in the literature (short foot exercise, tibialis posterior muscle strengthening, gastrocnemius stretching) (Haun et al., 2020; McKeon et al., 2015). It has been reported in the literature that individuals with pes planus have lower tibialis posterior and plantar flexor muscle strength and shorter Achilles tendons (Aenumulapalli et al., 2017). With the exercise protocol we used in the study, tibialis posterior strengthening and short foot strengthening exercises strengthen the intrinsic foot muscles, which are categorized as active subsystems in the foot core system. It improves foot-ankle neuromuscular control. Since the gastrocnemius muscle will shorten due to increased pronation, muscle function is increased by stretching this muscle (Wei et al., 2022). Thus, it is aimed to increase the activation of the arch muscles in a short time and provide functional gain. In the study, individuals in the exercise group were given the toe-up and down exercise for tibialis posterior muscle strengthening in 3 sets of 10 repetitions. Short foot exercise was given for 3 sets of 10 repetitions to strengthen the foot intrinsic muscle and to learn that they can elevate the medial longitudinal arch. Individuals were instructed to do the short foot exercise in a sitting position without putting any weight on their feet for the first 2 weeks, and then to do it while standing upright for 6 weeks. Another exercise given was the gastrocnemius stretching exercise, performed with one foot forward and leaning against the wall for 5 repetitions and 20 seconds. They were asked to do it every day for a total of 8 weeks. The exercises were given as a home program and individuals were asked to follow the program. Individuals were asked to create an exercise schedule, mark the days they did it and bring it back at the end of 8 weeks.

### Data Analyses

Assuming that the effect size that can be obtained with this study would be strong (d=0.8), it was calculated that 80% power could be reached at a 95% confidence level when 21 individuals (42 individuals in total) were included in the study for each group. Data were analyzed using IBM SPSS Statistics for Windows version 24.0 software (IBM Corp., Armonk, NY, USA). Mean Standard Deviation, Median, Minimum, Maximum values were given in descriptive statistics for continuous data, and percentage values were given for discrete data. Shapiro Wilk test was used to examine the suitability of the data for normal distribution. T test was used to compare normally distributed data in the exercise and control groups, and Mann Whitney U test was used to compare non-normally distributed data. Paired Sample T test (T test in dependent groups) was used to compare pre-treatment and post-treatment measurements of normally distributed data, and Wilcoxon test was used to compare non-normally distributed data with pre-treatment and post-treatment measurements. IBM SPSS Statistics 20 program was used in the evaluations and the statistical significance limit was determined as $p<0.05$.

## Results

When the demographic characteristics of the individuals participating in the study were examined, no difference was found between the age, height, weight, BMI values and gender distribution of the individuals in the insole group and insole plus exercise group ($p>0.05$; Table 1).

In the insole group and in the insole plus exercise group, a significant difference was found between the right and left foot navicular drop test scores in favour of post-treatment ($p<0.01$). There was no difference in the right and left foot navicular drop test scores before and after treatment between the two groups ($p>0.05$; Table 2). When the left foot navicular drop test differences of the individuals in the insole plus exercise and insole groups were examined before and after treatment, it was seen that there was no statistically significant difference ($p>0.05$). However, when the right foot navicular drop test differences were examined before and after treatment, a significant difference was found in favour of the insole plus exercise group ($p<0.01$; Table 3).

In the insole plus exercise and insole group, a significant difference was found in favor of post-treatment between pre-treatment and post-treatment FFI total scores ($p<0.001$). In the insole plus exercise and insole group, a significant difference was found in favor of post-treatment between pre-treatment and post-treatment FFI pain score, FFI inadequacy and FFI limitation scores ($p<0.001$; Table 4). When the FFI scores of the groups were compared; no difference was found between pre-treatment and post-treatment FFI pain, FFI inadequacy, FFI limitation and FFI total values of individuals in the insole plus exercise and insole groups ($p>0.05$; Table 5).

**Table 1**
Descriptive statistics, gender distributions and comparisons regarding age, height, weight and BMI values of adolescents in the insole plus exercise group and the insole group.

| Variables | Insole plus exercise (n=21) | | Insole (n=21) | | p* |
|---|---|---|---|---|---|
| | Mean ± SD | | Mean ± SD | | |
| Age (year) | 13.81 ± 2.86 | | 12.86 ± 2.73 | | 0.242 |
| Height(cm) | 161.24 ± 12.32 | | 160.76 ± 14.25 | | 0.908 |
| Weight (kg) | 55.02 ± 14.66 | | 53.33 ± 12.11 | | 0.686 |
| BMI (kg/m$^2$) | 20.86 ± 3.62 | | 20.47 ± 2.89 | | 0.700 |
| Sex | n | % | n | % | |
| Girl | 7 | 33.3 | 6 | 28.6 | 0.739 |
| Boy | 14 | 66.7 | 15 | 71.4 | |

** T test/ Mann Whitney U test / Chi-square test; SD: standard deviation; BMI: body mass index.*

**Table 2**
Comparisons of right and left foot navicular drop tests of adolescents in exercise plus insole and insole groups before and after treatment (Mean ± SD).

| Variables | | Insole plus exercise | Insole | p* |
|---|---|---|---|---|
| Right | B.T. NDT (weighted-weightless) (mm) | -12.05 ± 2.71 | -11.76 ± 3.03 | 0.749 |
| | A.T. NDT (weighted-weightless) (mm) | -10.19 ± 2.54 | -11.09 ± 2.81 | 0.280 |
| | p** | <0.001 | 0.001 | |
| Left | B.T. NDT (weighted-weightless) (mm) | -13.09 ± 4.28 | -11.76 ± 2.21 | 0.214 |
| | A.T. NDT (weighted-weightless) (mm) | -10.95 ± 3.46 | -10.90 ± 2.05 | 0.957 |
| | p** | <0.001 | <0.001 | |

** Unpaired t- test ** Paired Samples t- test; B.T.: Before treatment; A.T.: After treatment; NDT: Navicular Drop Test.*

**Table 3**
Comparison of the differences in pre-treatment and post-treatment navicular drop test scores between the exercise plus insole and insole groups (Mean ± SD).

| Variables | Insole plus exercise | Insole | p* |
|---|---|---|---|
| NDT Right foot difference (post-pre) | 1.86 ± 1.46 | 0.67 ± 0.79 | 0.005 |
| NDT Left foot difference (post-pre) | 2.14 ± 2.24 | 0.86 ± 0.91 | 0.099 |

** Mann Whitney U test; NDT: Navicular Drop Test.*

**Table 4**
Pre-treatment and post-treatment FFI comparisons of adolescents in the exercise plus insole and insole groups (Mean ± SD).

| Variables | Insole plus exercise | Insole | p* |
|---|---|---|---|
| Before treatment FFI pain | 45.14 ± 14.92 | 45.50 ± 16.15 | 0.941 |
| After treatment FFI pain | 15.76 ± 8.06 | 20.15 ± 10.62 | 0.140 |
| p** | <0.001 | <0.001 | |
| Before treatment FFI disability | 34.86 ± 19.61 | 32.90 ± 13.84 | 0.715 |
| After treatment FFI disability | 14.39 ± 11.93 | 16.09 ± 10.03 | 0.442 |
| p** | <0.001 | <0.001 | |
| Before treatment FFI limitation | 14.67 ± 10.59 | 12.00 ± 7.18 | 0.668 |
| After treatment FFI limitation | 3.43 ± 4.20 | 3.81 ± 3.99 | 0.735 |
| p** | <0.001 | <0.001 | |
| Before treatment FFI total | 33.45 ± 13.97 | 32.01 ± 11.21 | 0.714 |
| After treatment FFI total | 12.54 ± 7.55 | 15.00 ± 7.68 | 0.301 |
| p** | <0.001 | <0.001 | |

*** Paired samples t-test; * Mann Whitney U test; FFI: Foot Function Index.*

**Table 5**
Comparison of the differences in FFI scores before and after treatment between the exercise plus insole and insole groups (Mean ± SD).

| Variables | Insole plus exercise | Insole | p* |
|---|---|---|---|
| FFI pain difference (post-pre) | -29.37 ± 10.49 | -25.35 ± 11.83 | 0.308 |
| FFI disability difference (post-pre) | -20.48 ± 12.69 | -16.82 ± 9.36 | 0.345 |
| FFI limitation difference (post-pre) | -11.24 ± 11.14 | -8.19 ± 5.33 | 0.622 |
| FFI total difference (post-pre) | -20.91 ± 9.59 | -17.00 ± 7.92 | 0.094 |

** Mann Whitney U test; FFI: Foot Function Index.*

## Discussion

Our study was conducted to investigate the effects of CAD/CAM-produced insoles and exercises on foot function and MLA flexibility in adolescents aged 10-19 years diagnosed with painful flexible pes planus. Our findings showed that foot function index and navicular drop test values improved significantly in both groups, insole group and insole plus exercise group. No difference was found between the groups in terms of foot function index values. For navicular drop test results, more improvement was observed in the right foot in the insole plus exercise group compared to the insole group. These results provide information about the effects of CAD/CAM-produced insoles and exercises given with these insoles on the medial longitudinal arch and foot function for rehabilitation planned for painful pes planus.

The randomized controlled trial conducted by Andreasen et al. included four groups: standard intervention, custom-made insoles, insoles combined with exercise, and exercise groups. Unlike our study, it was reported that foot posture measurements, including NDT, did not change significantly after 12 weeks of interventions and the effects of the four interventions mentioned above were not significantly different. The aims of the exercises were given in the study, but no detailed information was given about which exercises were given and the duration of insole use. In addition, all interventions were implemented as a home program as in our study. However, no data was provided about the participants' compliance with the program (Andreasen et al., 2013). In a study conducted by Kim and Kim in 2016 to examine the effects of short foot exercises and arch-supported insoles on arch improvement and dynamic balance in individuals with flexible pes planus, they found that exercise was more effective on the navicular drop test score than arch-supported insoles (Kim & Kim, 2016). Kırmızı et al. conducted a study to determine the effects of exercise, custom arch-supported insoles, and exercise plus insoles on foot posture, plantar force distribution, and balance in individuals with flexible pes planus. Three groups of individuals with flexible pes planus were given separate exercises, custom insoles, and exercise plus insole interventions for six weeks. Similar to our study, it was reported that foot posture assessed with NDT improved in all groups, but the exercise plus insole group was superior (Kırmızı et al., 2024). In a study conducted in individuals with flexible pes planus, in accordance with the type of exercise given in our study, tibialis posterior exercises together with short foot exercises increased the strength of the tibialis posterior and peroneus longus muscles supporting the MLA, provided dynamic balance control, and reduced plantar pressure (Sukprasert et al., 2024). There are also studies showing that only short foot exercises and intrinsic muscle activity without using insoles are effective on navicular drop test scores in individuals with pes planus (Ünver et al., 2019; Mulligan & Cook, 2013; Jung et al., 2011; Fiolkowski et al., 2003). In our study, the navicular drop test scores of the groups decreased significantly after treatment. However, when the navicular drop test differences between the two groups were examined, a significant difference was found in the group given insoles plus exercise, especially in favor of the right foot. It was seen that the exercise was more effective in improving the navicular height than the group given only insoles. Although no significant difference was found between the right and left feet in the initial data, we think that the reason why the result is particularly significant on the right foot is because the right foot is dominant and the exercise is easier to perform and adapt to on that foot. We think that if the 8-week follow-up results in our study were done for a longer period of time and the exercise was done in a clinical environment with a physiotherapist, these results would be more positively affected.

A systematic review and meta-analysis by Cheng et al. showed that there was no significant difference in the navicular drop test and foot stance index improvement when short foot exercises were compared with the control groups. It was stated that only short foot exercises lasting longer than 6 weeks showed a significant improvement in navicular drop test, which is consistent with the exercise duration in our study. Unlike existing clinical randomized controlled trials, this meta-analysis does not prove that short foot exercises are fully effective in improving NDT in patients with pes planus. It was stated that a larger sample size is needed to find out the effects of short foot exercises in improving pes planus (Cheng et al., 2024).

In pes planus deformity, the load given to the medial side of the foot increases with the decrease in the medial longitudinal arch. As a result, angular changes occur in the lower extremity. This affects the foot biomechanics and causes symptoms such as pain, loss of strength, fatigue and functional limitations. (Sheikh Taha et al., 2015) In a study conducted to examine the effects of different foot orthoses on pain and health-related quality of life in painful flexible pes planus patients, it was reported that CAD/CAM insoles were an effective method to relieve pain and improve quality of life (Yurt et al., 2019). In a study conducted to compare the effects of personalized 3D insoles and prefabricated insoles on plantar pressure and comfort in patients with symptomatic pes planus, personalized 3D printed insoles reduced the pressure on the metatarsals by distributing it to the midfoot region and reduced the damage caused by symptomatic pes planus. It has been stated that the personalized 3D printed insoles we used in our study are more effective than prefabricated insoles and provide better comfort for patients with symptomatic pes planus (Xu et al., 2019). In the review conducted by Sultani & Fatahi (2024), it was reported that the use of corrective exercises, especially the use of orthotics and various medical insoles, including therapeutic interventions, helped treat and improve the symptoms of pes planus. In line with the literature, in our study, the FFI total score and sub parameters showed significant improvement after treatment in both groups. Since the insoles and exercise minimized the biomechanical imbalances of individuals by supporting the medial longitudinal arch, they had a positive effect on pain, disability and activity limitation. In the study conducted by Elsayed et al. to examine the effects of short foot exercises with insoles and insoles alone on foot pressure measurements, pain, function and navicular drop in individuals with symptomatic flexible pes planus, participants were followed for six weeks. It was stated that there was an improvement in pain and function in both groups mentioned above. However, unlike our study, exercise with insoles was found to be more effective than insoles alone (Elsayed et al., 2023). According to FFI analyses, individuals in the insole plus exercise group did not outperform the insole group alone. This may be due to the fact that the exercises were given as a home program and the participation in the exercise was approximately 60%. Since exercise compliance is not very high, it is not possible to make a definitive judgment about the functional benefit of exercise. Considering this situation, it is thought that further studies should be conducted with higher participation and supervised exercise programs. The use of different measurement methods to assess pain and function in studies makes it difficult to compare results. Only one study was found in the literature that used FFI to assess function in individuals with flexible pes planus (Yurt et al., 2019). We believe that more studies are needed on this subject.

In the comments sent by the families of the adolescents who participated in our study, we were informed that the fall rates decreased for both groups and the satisfaction levels were high. In our study, a longer follow-up instead of an 8-week follow-up of the exercise program could have provided more effective results. At the same time, imaging the effects of the applied exercises with ultrasonography after the treatment and evaluating the cross-sectional areas of the muscles could have increased the power of our study in favor of exercise.

The limitations of our study are; exercises were given as a home program, but there was no supervision by a physiotherapist, the long-term effects of the exercise and insoles could not be determined after 8 weeks of follow-up, and due to the COVID-19 pandemic, the insoles were used only at home for some individuals and the duration of use during the day varied, there were delays in following the exercises, and there were difficulties in implementing post-treatment evaluations due to the pandemic. Since our study was limited to right dominant individuals, the generalization of the results to left dominant or bilateral dominant individuals is limited. It is recommended that this limitation be overcome by including individuals with different dominance characteristics in future studies.

## Conclusion

As a result; it was found that the use of CAD/CAM insoles improved FFI parameters in adolescents with painful flexible pes planus. However, it was found that the effects of insoles and exercise together with insoles on these parameters were similar and that exercise has no additional benefit over insoles. However, exercise combined with insoles was found to be more effective in improving the amount of navicular drop. We think that physiotherapists working in the field of orthopedics and pediatrics should take into account muscle weakness and shortness for individuals and children with flexible pes planus, recommend appropriate orthotic support if necessary, and create an appropriate exercise protocol for these individuals with other studies.

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### Authors' Contribution

Study Design: İB, OTA, SE; Data Collection: HA, İB; Statistical Analysis: İB, OTA, SE, ŞB; Manuscript Preparation: İB, OTA, SE, ŞB; Funds Collection: None.

### Ethical Approval

The study was approved by the Pamukkale University Clinical Research and Ethics Institution on 22.01.2019 with the file number 60116787-020/5952 and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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The authors declare that the study received no funding.

### Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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